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TWO CASE STUDIES OF MOS TEMPERATURE FORECAST INCONSISTENCIES AT BROWNSVILLE, TEXAS DURING THE WINTER OF 1983-1984

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1. INTRODUCTION

At the request of the National Weather Service's Southern Region Headquarters, the Techniques Development Laboratory investigated two recent cases with inconsistencies in the Model Output Statistics (MOS) temperature guidance for Brownsville, Texas. The forecasts were generated from the 0000 GMT Limited-area Fine Mesh (LFM) model (Gerrity, 1977; Newell and Deaven, 1981) runs of December 24, 1983, and January 20, 1984. In the first case, the minimum (min) temperature at Brownsville for December 25 was forecast to be 5°F higher than the maximum (max) temperature valid the same day. In the second case, the min and max temperatures forecast for January 21 were equal--not impossible, but highly suspicious since min/max temperature spreads of at least 10°F were forecast at most stations farther north. Furthermore, in both cases, the MOS 3-hourly temperature guidance was meteorologically inconsistent with respect to the min and max forecasts; that is, the min (max) temperature was forecast to be greater (less) than the midnight to midnight extremes indicated by the 3-hourly guidance. In addition to the inconsistencies, the max and min temperature forecasts themselves were very inaccurate when compared to the verifying observations.

For both the December 24 and January 20 cases, we recalculated the appropriate forecasts at Brownsville, and examined the general synoptic patterns to gain an understanding of the inconsistent MOS guidance. Also, we computed and assessed the usefulness of "perfect model" forecasts, whereby actual or estimated verifying LFM model fields were substituted into the MOS forecast equations. Investigation of this technique is of interest to see if the guidance can be improved by modifying those model forecast fields suspected of being in error before evaluating the MOS equations.

2. BACKGROUND

The MOS max/min temperature guidance is generated by linear regression equations (Glahn and Lowry, 1972) which relate observations of surface temperature to forecasts from the LFM model (predictors). The guidance is available twice daily, about 4 hours after the LFM model run, in both graphical and alphanumeric form. From the 0000 GMT cycle, forecasts of calendar day extremes (midnight to midnight local time) are generated for today's max, tomorrow's min and max, and the day after tomorrow's min, which are often valid approximately 24, 36, 48, and 60 hours, respectively, after 0000 GMT. Analogously, from 1200 GMT model output, forecasts of tomorrow's min, tomorrow's max, and the day after tomorrow's min and max are produced. Temperature forecasts valid every three hours from 6 through 51 hours after 0000 or 1200 GMT are also available. The 3-hourly temperature equations were

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developed simultaneously with the max/min equations in an attempt to promote consistency among the MOS temperature forecasts.

Forecasts through 36 hours of the max/min and 3-hourly temperatures are usually generated from primary equations which, along with the LFM fields, include recent surface observations and climatic terms as potential predictors. If observations are not available at forecast time, the guidance is generated from backup equations which use only LFM predictors and climatic terms. At projections greater than 36 hours, all forecasts are made from equations containing LFM predictors and climatic terms. For additional details, see National Weather Service (1980) or Dallavalle et al. (1980).

As an example of how a MOS forecast is calculated from a linear regression equation, Table 1 shows the term-by-term evaluation of tomorrow's min temperature forecast (from the primary equation) at Brownsville (BRO) for the December 24 case. Fig. 1 shows the observed hourly temperatures and the forecasts from both primary and backup equations[2] of tomorrow's min, tomorrow's max, and the 3-hourly temperatures valid from 24 through 51 hours after 0000 GMT on December 24. The analogous information for the January case is plotted in Fig. 2. In the December case, the 24- through 36-h guidance sent to the field was generated from backup equations since a surface observation required in the primary equations was unavailable. All operational forecasts in the January case were generated from primary equations. Forecasts valid before 24 hours from 0000 GMT were not included in either case study and are not plotted here.

Note in Fig. 1 that the 3-hourly guidance erroneously portends a dramatic warming beginning around the 24-h projection, with temperatures forecast to climb into the 40's by late Christmas Day. The trend is most conspicuous in forecasts from the backup equations. Clearly, for the 24- to 36-h projections, the operational guidance produced by the backup equations was much less accurate than what would have been generated by the primary equations. Also, tomorrow's min temperature predicted by the primary (backup) equation is 8°F (10°F) higher than the midnight to midnight min temperature suggested by the corresponding 3-hourly curve. Similarly, the forecast max temperature is 8°F lower than the maximum 3-hourly forecast. In contrast, for the January case, Fig. 2 shows a tendency for the 3-hourly forecasts to be too cold, particularly in the primary forecasts. Again, tomorrow's min and max temperature are forecast to the "wrong sides" of the 3-hourly curve. Note that in this case the backup equations produced more accurate guidance for the 24- through 36-h projections. However, tomorrow's min temperature forecast remains inconsistent with the hourly guidance.

Figs. 3 and 4 show the same projections as Figs. 1 and 2, respectively, except that these forecasts were generated by using actual or estimated verifying LFM fields. We might term this the "perfect model" application. For example, if the 0000 GMT equation for tomorrow's min required a 36-h LFM

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[2] Although both primary and backup forecasts are shown, only one set is disseminated operationally; the forecaster can not determine in real-time whether primary or backup equations were used to generate the guidance.

forecast, we substituted the verifying field from the 1200 GMT analysis of either December 25 or January 21. Any LFM forecasts valid 18, 30, or 42 hours after 0000 GMT were estimated with a simple average of the values verifying 6 hours before and after. We then recalculated the guidance after making all appropriate substitutions.

The graphs in Figs. 3 and 4 indicate that the 3-hourly guidance made from perfect model forecasts has a predominantly cold bias. An exception is in the December case, when the temperature forecasts valid after 36 hours from 0000 GMT are rather good. In addition, with the exception of the max for December 25, the inconsistency problem remains with the predicted 3-hourly temperatures and the max/min guidance.

3. DISCUSSION

The inaccurate MOS forecasts in both the December and January cases become somewhat more understandable when the overall synoptic situations are considered. Figs. 5, 6, and 7 show the 24-, 36-, and 48-h LFM forecasts, respectively, of the 1000-500 mb thickness from 0000 GMT on December 24 and the verifying analyses. Likewise, Figs. 8, 9, and 10 show the forecasts and verifying analyses for the January case. Clearly, unseasonably cold air masses affected southern Texas in both cases, and the LFM handled the situations with varying degrees of success.

In the December case, the LFM forecast a significant warming in the region, at least in terms of the 1000-500 mb thickness, which simply did not occur. Errors in the thickness forecasts exceeded 100 m in southern Texas for the 48-h projection. The operational MOS guidance (Fig. 1) merely reflected the tendency of the model, resulting in a warm bias in the temperature forecasts after 24 hours. If the dynamical model handles a situation unsatisfactorily, MOS generally will not produce a good forecast since the MOS technique accounts for systematic biases but not erroneous model forecasts as was the situation here. Note that when the "perfect model" forecasts were used (Fig. 3), the MOS guidance did improve, at least after the 36-h projection. The forecaster should, of course, be wary of the MOS forecasts if he or she suspects an incorrect evolution of events in the dynamical model.

In contrast, as Figs. 8, 9, and 10 demonstrate, the LFM handled the January case reasonably well. Nevertheless, both the operational and "perfect model" MOS guidance were very inaccurate. Therefore, a good dynamical model forecast does not guarantee accurate statistical guidance.

It is important to note the extreme weather conditions in both cases. The min (max) temperature at Brownsville on December 25 was 32°F (41°F) below the 1941-70 normal value. Departures from normal in the January case were 16°F and 26°F for the min and max temperature, respectively. Under such circumstances, the MOS relationships may not be valid because few, if any, cases this extreme would have been included in the developmental sample. Therefore, it isn't unusual to find large forecast errors as well as inconsistencies in the min, max, and 3-hourly temperature guidance when the weather conditions are extremely anomalous. We suspect this may have been a primary factor in the January case, considering that the LFM forecasts were reasonably good. Dallavalle (1984) and Murphy and Dallavalle (1984) discuss the problem of deviations from normal for other cases.

In addition, physical factors not explicitly accounted for by either MOS or the LFM, such as ground moisture and soil temperature, often become important enough to affect profoundly the air temperature. Several very cold air masses had already swept across the southern Plains before the Christmas outbreak. It's likely that ground temperatures were lowered enough to suppress the air temperatures, and that snow cover farther north inhibited the normal modification of the airmass as it pushed southward. MOS has no explicit way of accounting for these factors. Until such effects can be included in future MOS development, users of the MOS forecasts should recognize this limitation and modify the guidance accordingly.

Comparing the guidance for spatial consistency can be useful in determining whether a forecast is suspect.[3] Fig. 11 shows the forecast minima in the Texas area for December 25. Fig. 12 is a similar plot of the maxima for January 21. The forecast of 41°F at Brownsville in the first case and the forecasts of 25°F at both Brownsville and Corpus Christi in the second case seem to differ greatly from the other temperatures in the region. With a knowledge of the climatic differences among local stations, the forecaster should be able to determine whether such guidance is reasonable.

As Table 2 shows, substituting modified LFM fields into the MOS equations in an effort to improve the guidance is a risky proposition. The mean absolute errors of the primary 3-hourly guidance (24 through 36 hours) generated from the actual LFM forecasts and the corresponding perfect model forecasts for BRO were 3.6°F and 7.8°F, respectively, for the December case; the analogous errors for the January case were 12.5°F and 10.0°F, respectively. The mean absolute errors for the min and max temperature forecasts and for the 39- through 51-h guidance were decreased in the perfect model approach, with the greatest change occurring in the December case. Although these figures indicate some overall improvement in terms of absolute error by using the perfect model fields, the guidance is still generally inconsistent and, for the January case, very inaccurate.

In this study, we had the luxury of knowing all of the exact fields to substitute into the MOS equations. It is highly unlikely that an operational meteorologist could correct the LFM so perfectly. Also, since the predictors in the equation are related both statistically and meteorologically, it may be risky to change one field without adjusting all of the others. Finally, the practice is not completely justifiable because it disregards any biases and systematic errors in the LFM for which MOS compensates. We suspect that the perfect model forecasts improve the MOS guidance to the extent that the regression equations are based on physically meaningful relationships. From a statistical viewpoint, the perfect model approach violates conditions under which the equations were developed. Probably, the forecaster could subjectively adjust the MOS guidance itself more effectively than adjusting model forecast fields.

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[3] On AFOS, the plotted MOS max/min temperature forecasts for the approximately 24-, 36-, 48-, and 60-h projections are available as graphic products P4X, P6X, P8X, and P9X, respectively.

4. SUMMARY

We investigated occurrences of meteorologically inconsistent MOS max/min and 3-hourly temperature forecasts from 0000 GMT LFM output of December 24, 1983, and January 20, 1984. The study concentrated on Brownsville, Texas where the problems were most pronounced. In addition to relating the errors in the guidance to the overall synoptic situation, we examined the usefulness of modifying the LFM fields in the MOS equations by noting the effect perfect LFM forecasts would have had on the objective guidance.

Not surprisingly, the results sugggest that MOS generally responds to trends forecast by the LFM. The statistical relationships can account for systematic model biases, but not for erroneous model forecasts. This was most evident in the December case when inaccurate LFM forecasts of strong warming in southern Texas produced MOS guidance that was much too warm.

Another important factor was the extremity of the weather in both cases. In such anomalous situations, the validity of the statistical relationships and, therefore, the quality and consistency of the guidance, may break down. In addition, surface effects that MOS does not explicitly account for, such as unusual ground moisture and soil temperature conditions, may have contributed to forecast errors. The inherent uncertainty in the MOS forecast equations is due both to lack of accuracy in the LFM and to the fact that not every physical parameter that influences the surface air temperature is included in the regression model.

Finally, substituting perfect model forecasts into the MOS equations produced mixed results. It is doubtful that a forecaster's effort of altering the LFM fields and recalculating the MOS guidance would be any better than making a subjective adjustment to the original MOS forecast itself. Obviously, in an operational situation, the forecaster does not know the perfect model forecast.

5. ACKNOWLEDGMENTS

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Table 1. Computation of tomorrow's min temperature valid December 25, 1983, at BRO (primary equation) from output of 0000 GMT December 24, 1983.

Predictor	Projection or Observation Time	Coefficient	LFM or Observed Value	Contribution
850-mb temperature (K)	30	0.8198	279.1853	228.8761
Observed sfc v component (kt)	3	0.0372	-9.2	-0.3422
850-mb v component (m/s)	36	0.6207	9.8615	6.1210
1000-mb dew point (K)	24	0.1334	265.0305	35.3551
1000-mb temperature (K)	36	0.4998	275.5198	137.7048
850-mb dew point depression (K)	24	-0.1824	4.8460	-0.8839
Observed sfc temperature (°F)	0	0.1360	39.0	5.3040
750-mb vertical velocity (mb/s)	36	1755.8999	-0.0007	1.2291
Observed sfc wind speed (kt)	3	-0.3391	12.0	-4.0692
Cosine day of the year	-	-11.0050	0.9927	-10.9247
Observed sfc dew point (°F)	3	-0.0047	37.0	-0.1739
850-700 mb thickness (m)	36	-0.0379	1597.6409	-60.5506

Constant of regression = -302.130 MOS = 33.0574

Table 2. Mean absolute errors (°F) for the MOS guidance generated from 0000 GMT LFM data on December 24, 1983, and January 20, 1984. Errors are given for both primary (PRI) and backup (BKUP) equations, where appropriate. Guidance generated from both actual LFM fields (ACTUAL) and perfect model forecasts (PERFECT) was evaluated.

Forecast Type	DECEMBER		JANUARY	
	ACTUAL	PERFECT	ACTUAL	PERFECT
24- through 36-h temp (PRI)	3.6	7.8	12.5	10.0
24- through 36-h temp (BKUP)	8.6	7.0	9.5	10.2
Tomorrow's min temp (PRI)	11.0	1.0	10.0	8.0
Tomorrow's min temp (BKUP)	21.0	4.0	8.0	5.0
Tomorrow's max temp	6.0	1.0	18.0	13.0
39- through 51-h temp	11.0	1.8	14.0	10.0

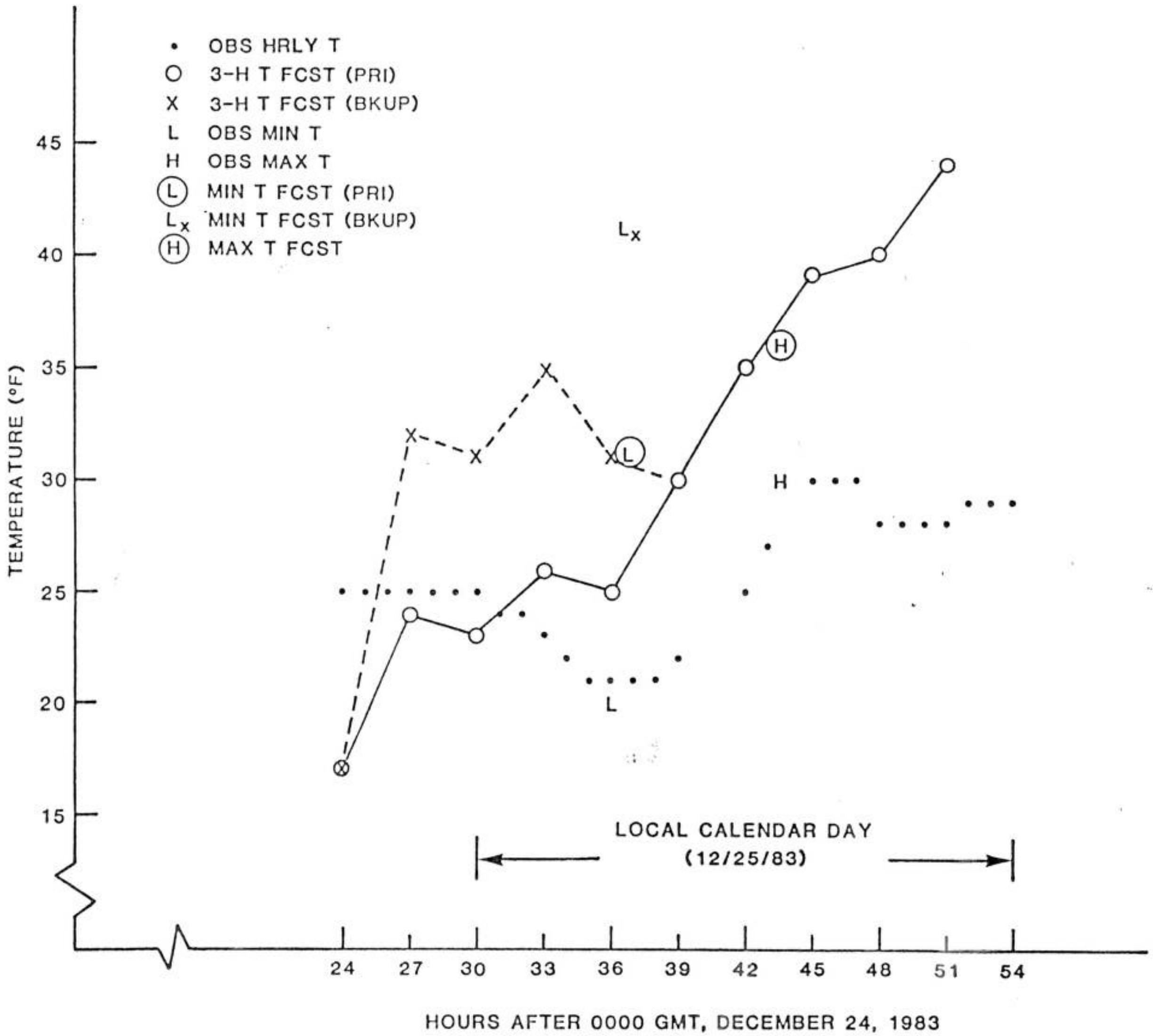

Figure 1. MOS forecasts of the 3-hourly temperatures, tomorrow's min, and tomorrow's max from 0000 GMT LFM data on December 24, 1983. Guidance generated from both primary (PRI) and backup (BKUP) equations is shown. In this case, the operational forecasts for 24 through 36 hours were from backup equations. The observed temperatures are also plotted.

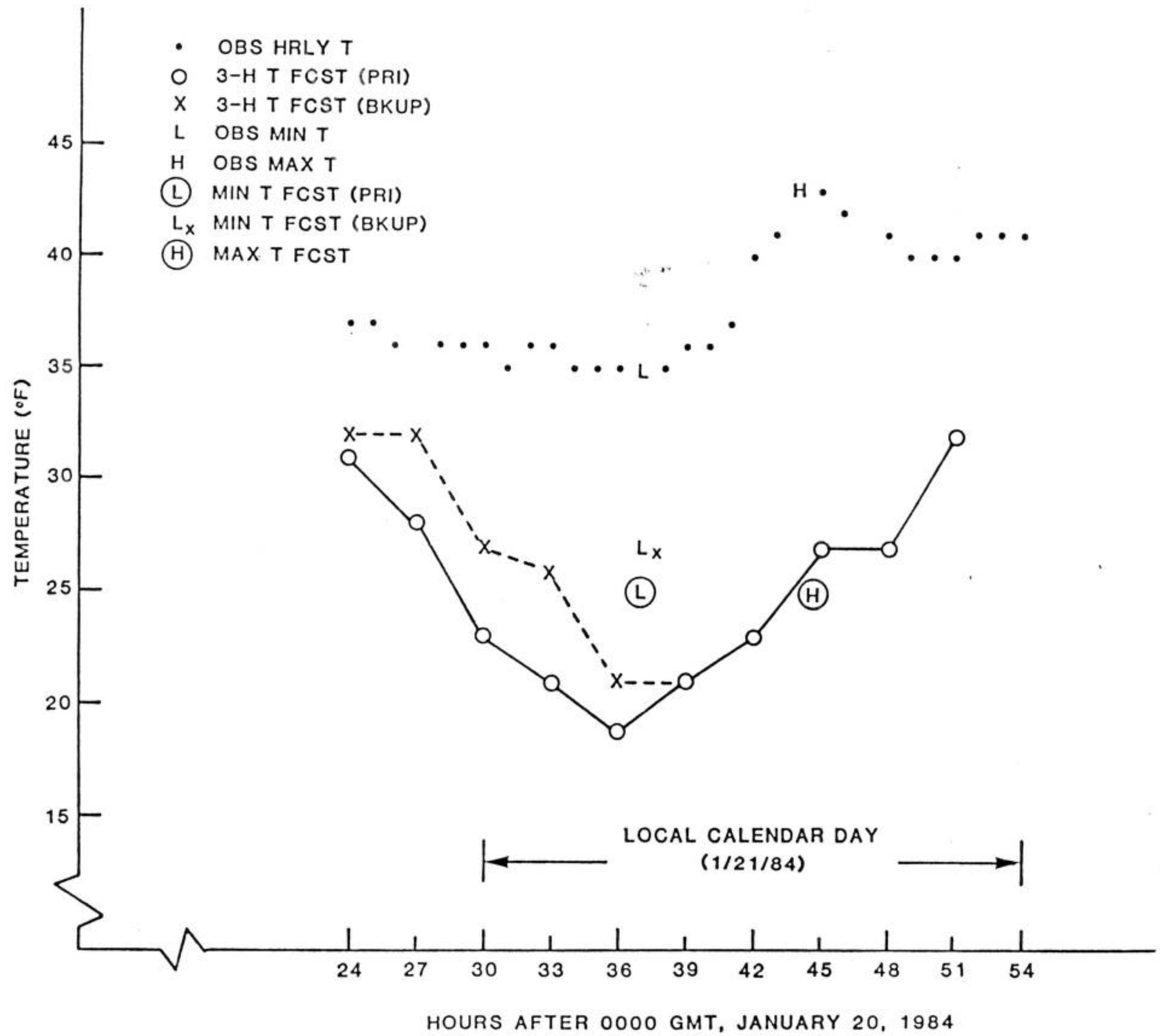

Figure 2. Same as Fig. 1 except from 0000 GMT LFM data on January 20, 1984. In this case, the operational forecasts for 24 through 36 hours were generated from the primary equations.

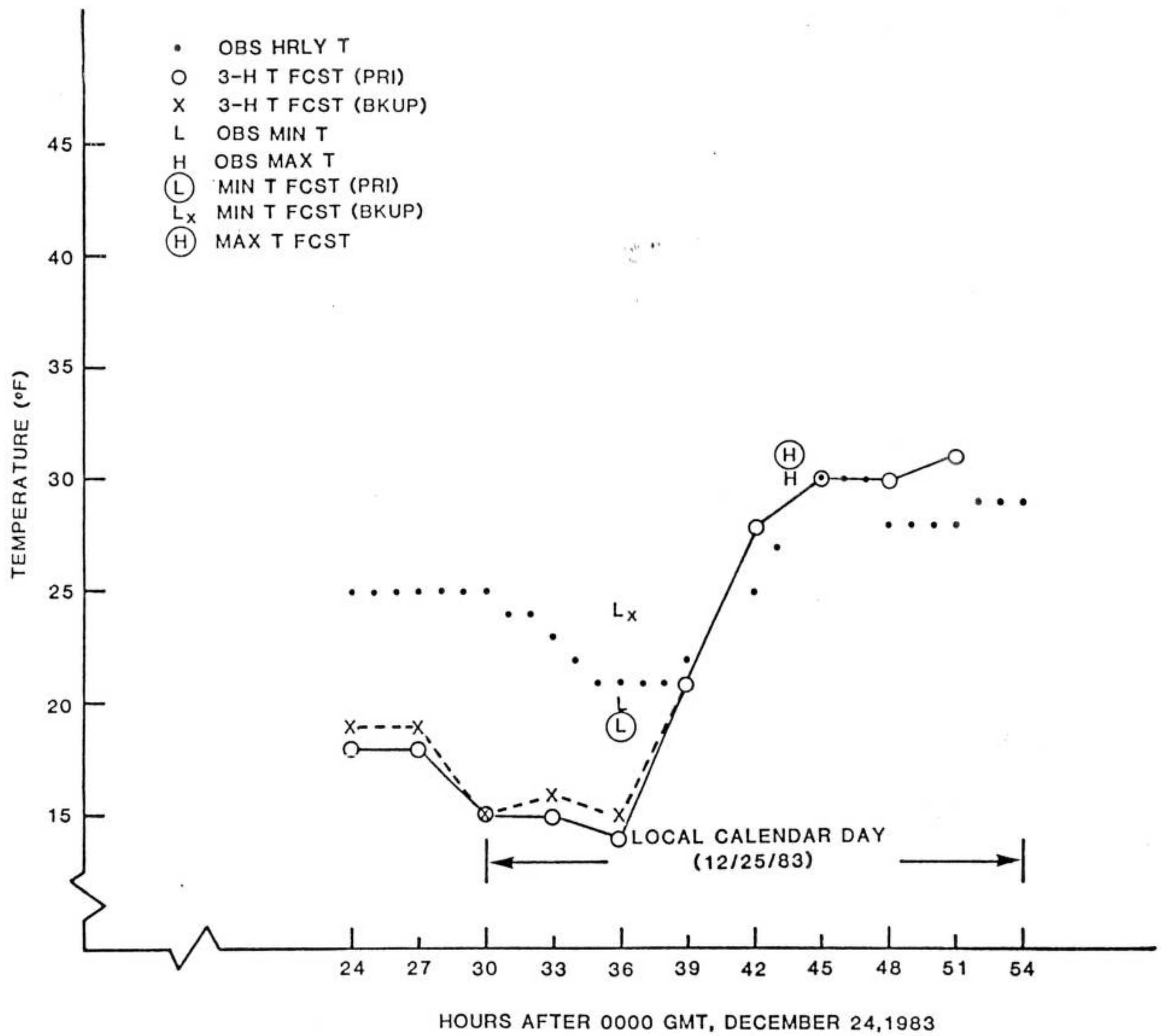

Figure 3. Same as Fig. 1 except the MOS forecasts were generated by perfect model output, that is, verifying LFM analyses of December 25-26, 1983.

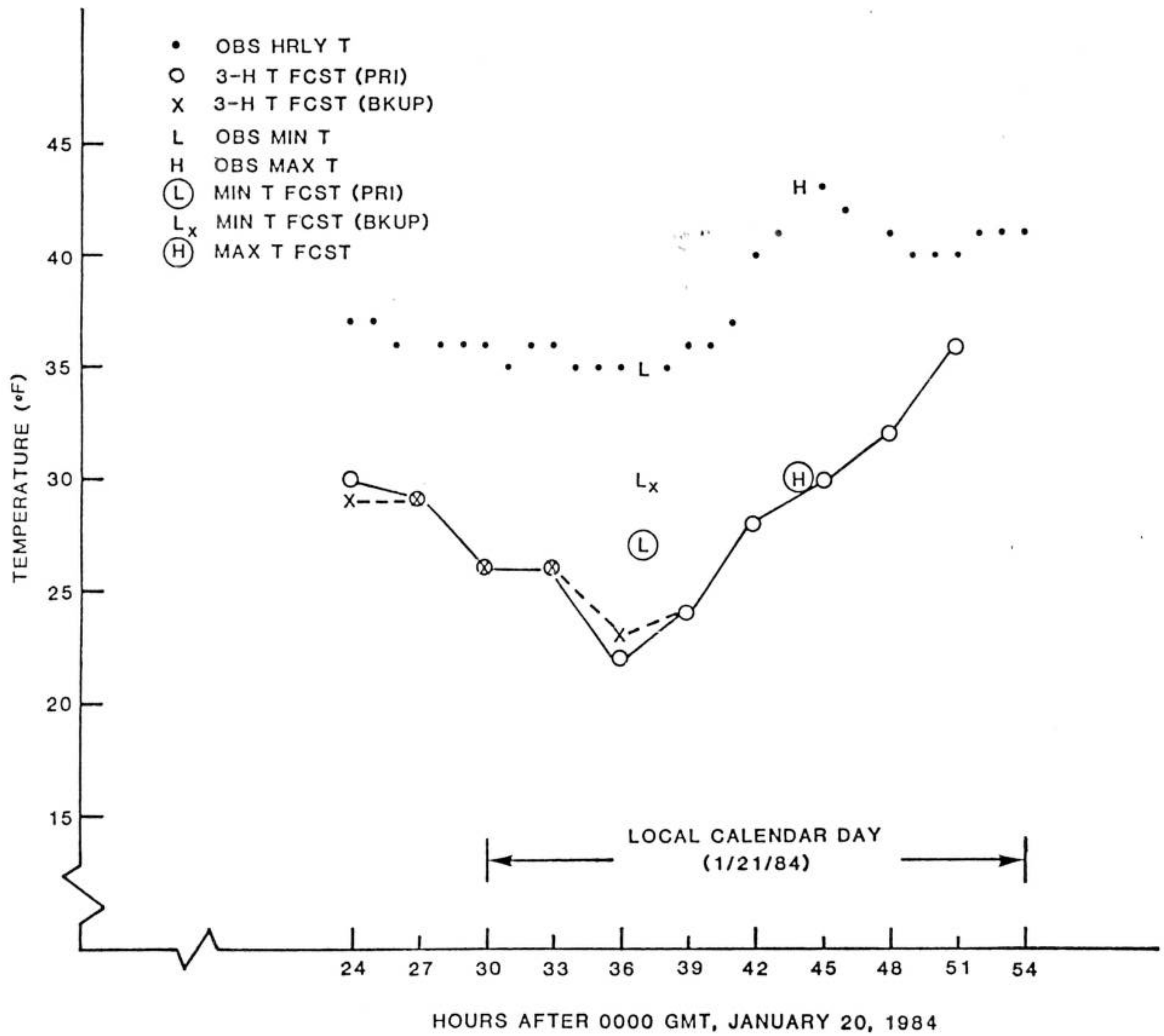

Figure 4. Same as Fig. 2 except forecasts were generated from verifying LFM analyses of January 21-22, 1984.

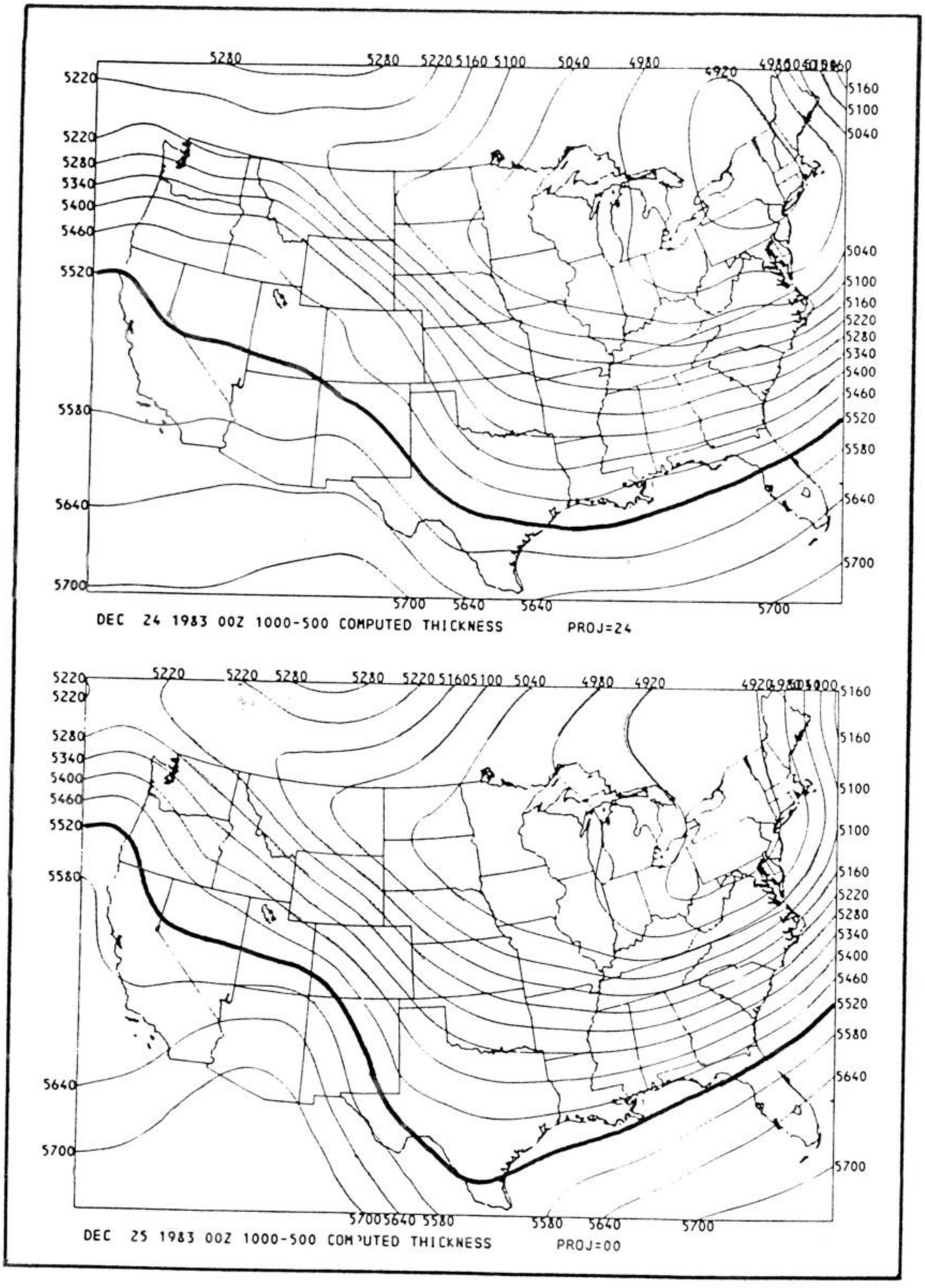

Figure 5. The 24-h LFM forecast 1000-500 mb thickness valid 0000 GMT, December 25, 1983 (top) with the verifying analysis (bottom). The 5520 m contour is highlighted.

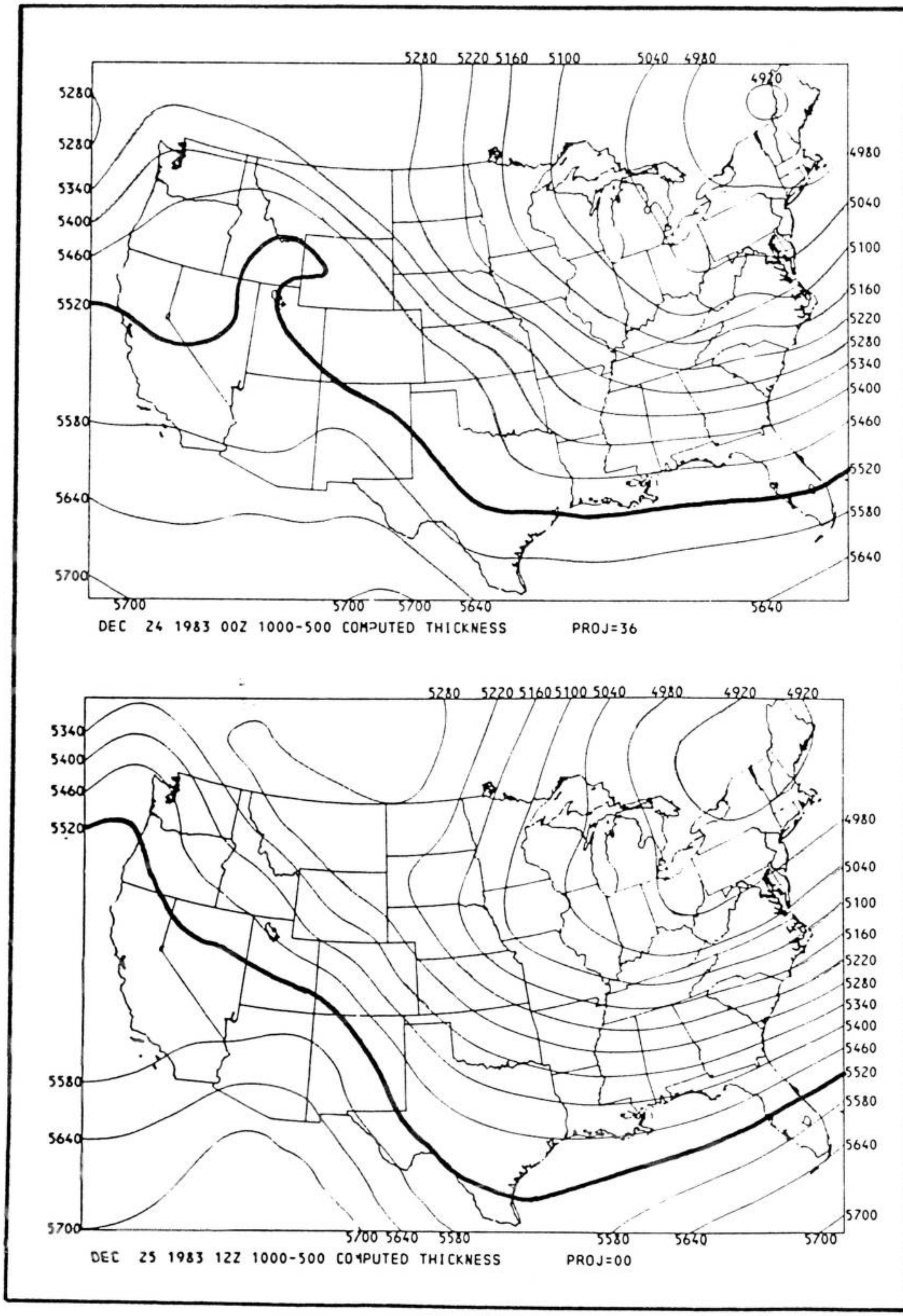

Figure 6. Same as Fig. 5 except the 36-h forecast and analysis are valid 1200 GMT, December 25, 1983.

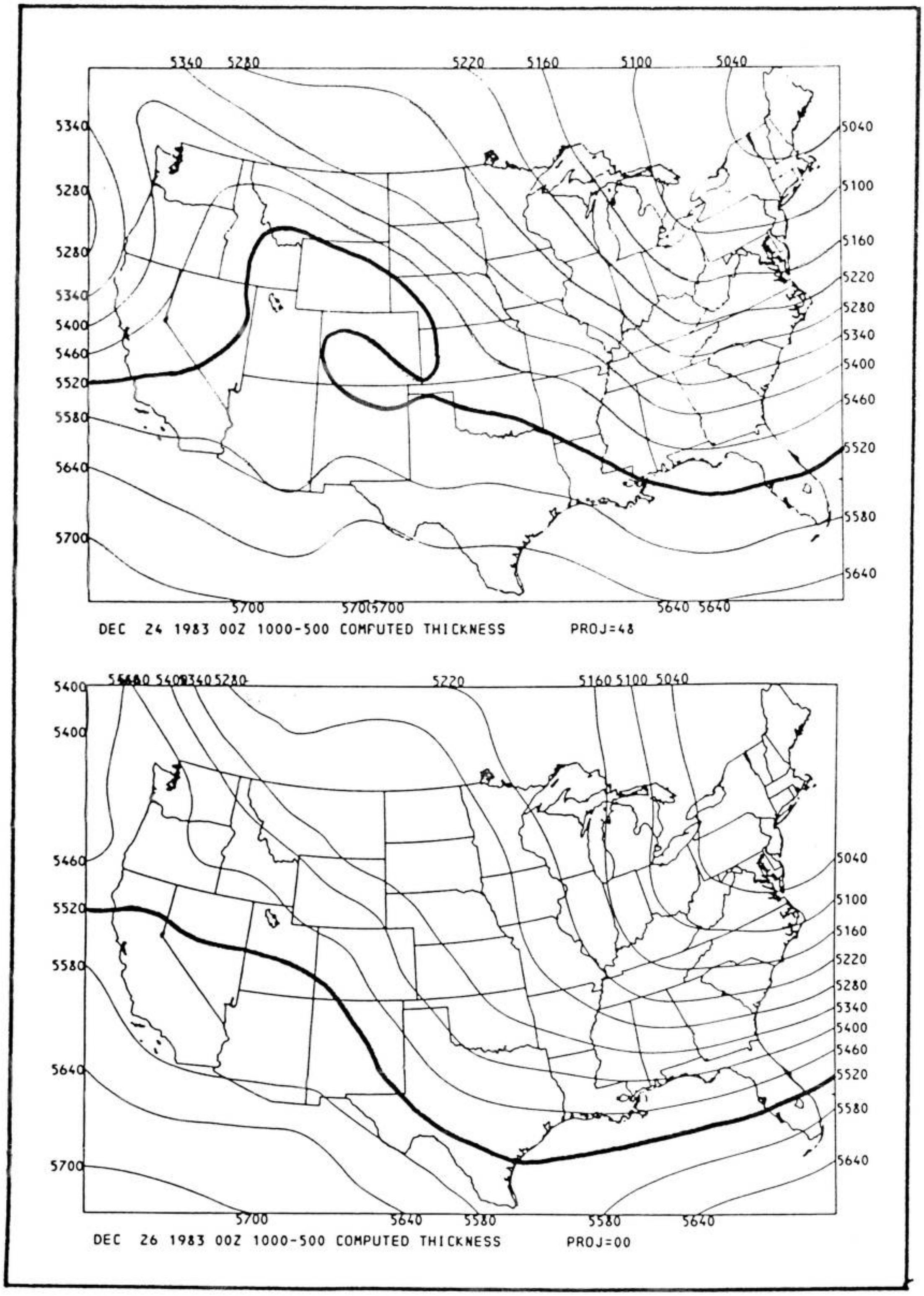

Figure 7. Same as Fig. 5 except the 48-h forecast and analysis are valid 0000 GMT, December 26, 1983.

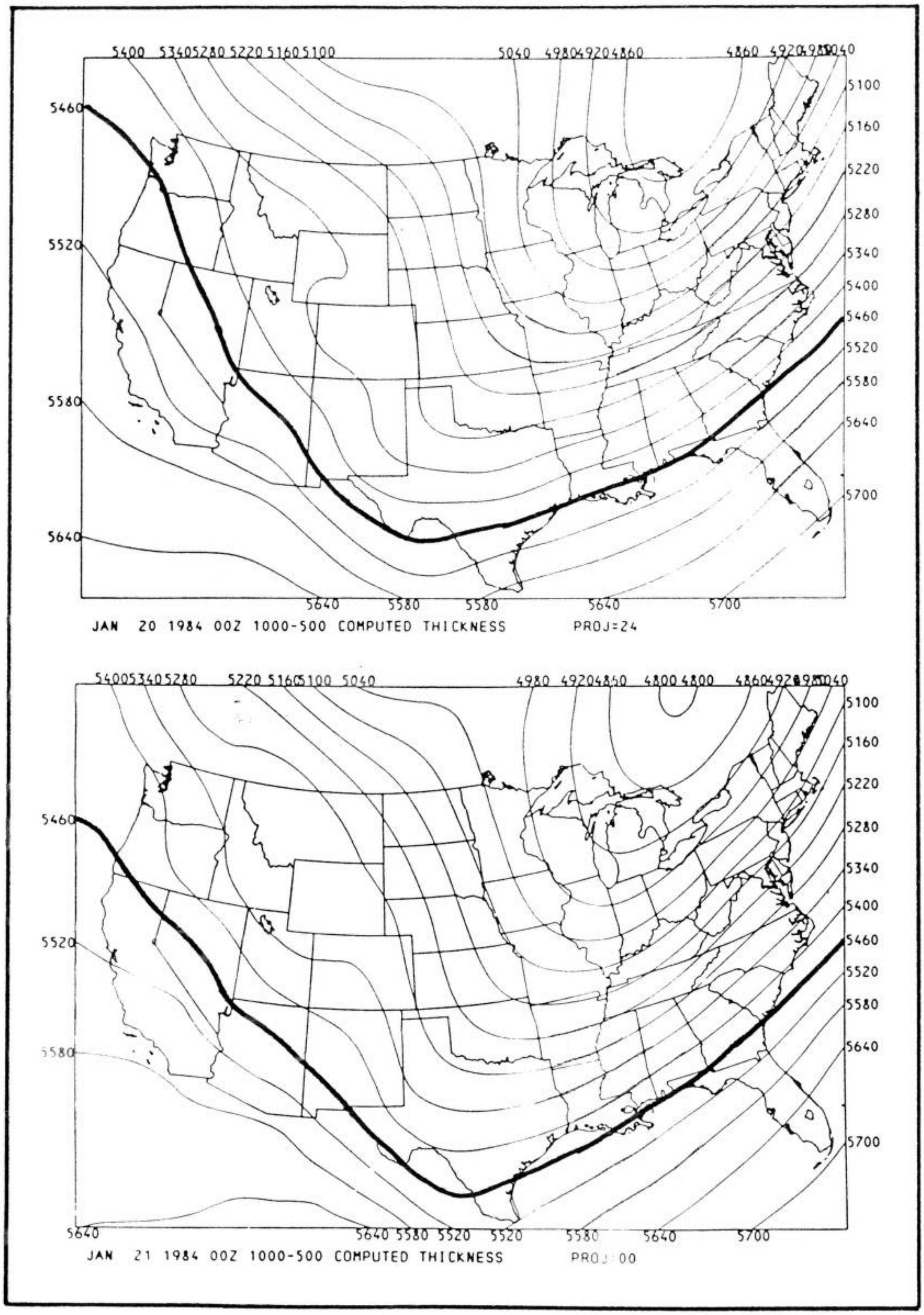

Figure 8. The 24-h LFM forecast 1000-500 mb thickness valid 0000 GMT, January 21, 1984 (top) with the verifying analysis (bottom). The 5460 m contour is highlighted.

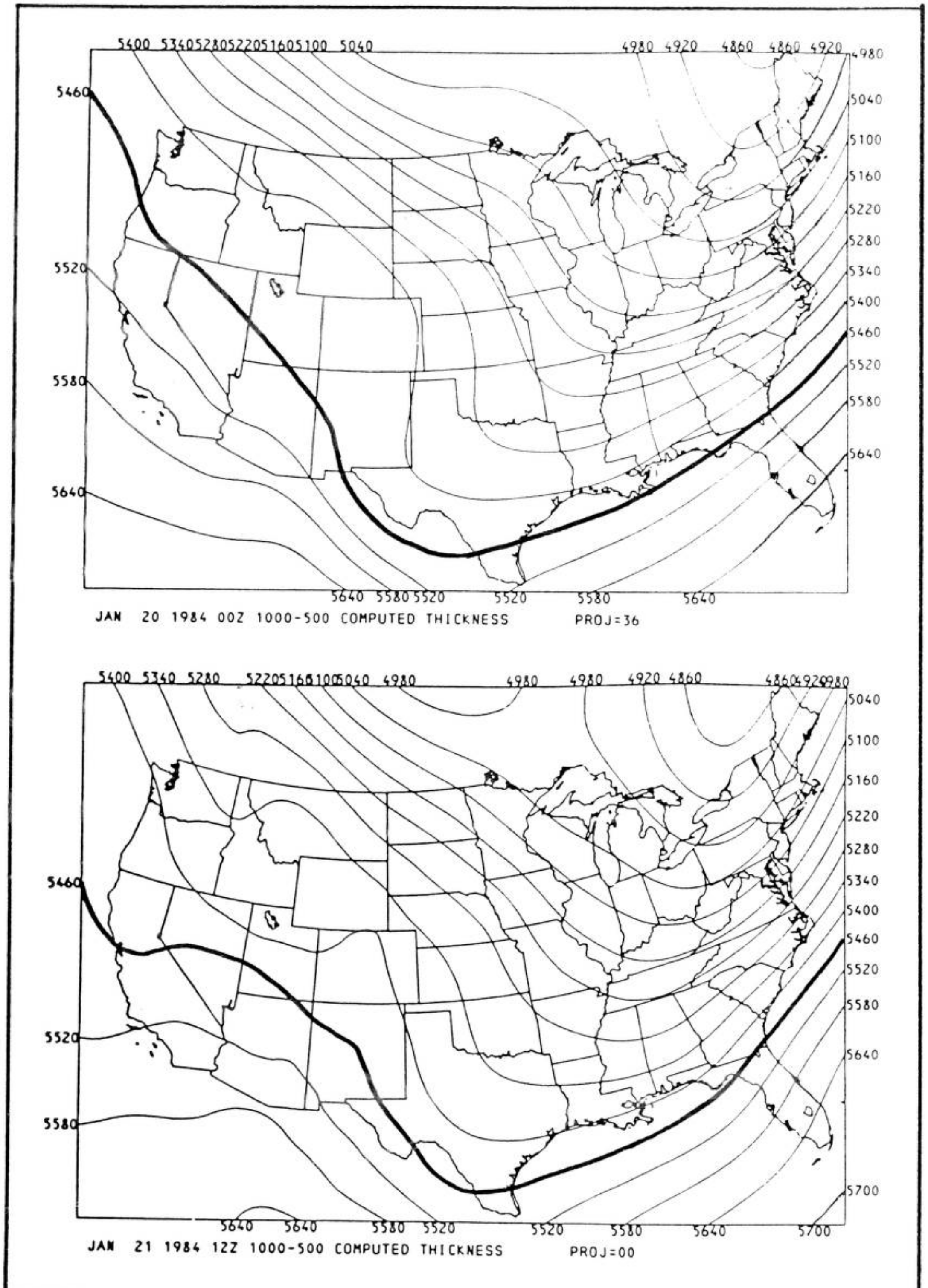

Figure 9. Same as Fig. 8 except the 36-h forecast and analysis are valid 1200 GMT, January 21, 1984.

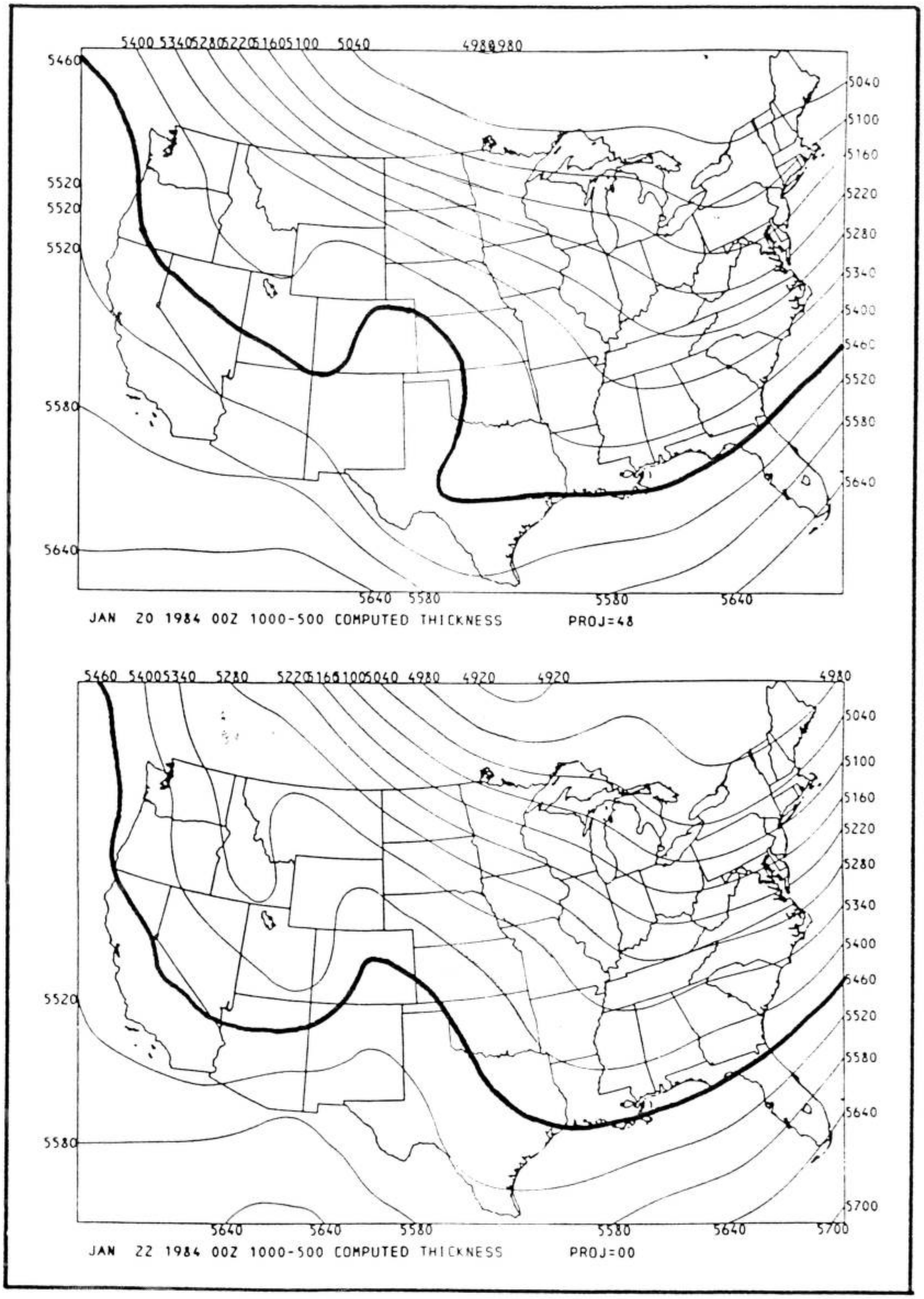

Figure 10. Same as Fig. 8 except the 48-h forecast and analysis are valid 0000 GMT, January 22, 1984.

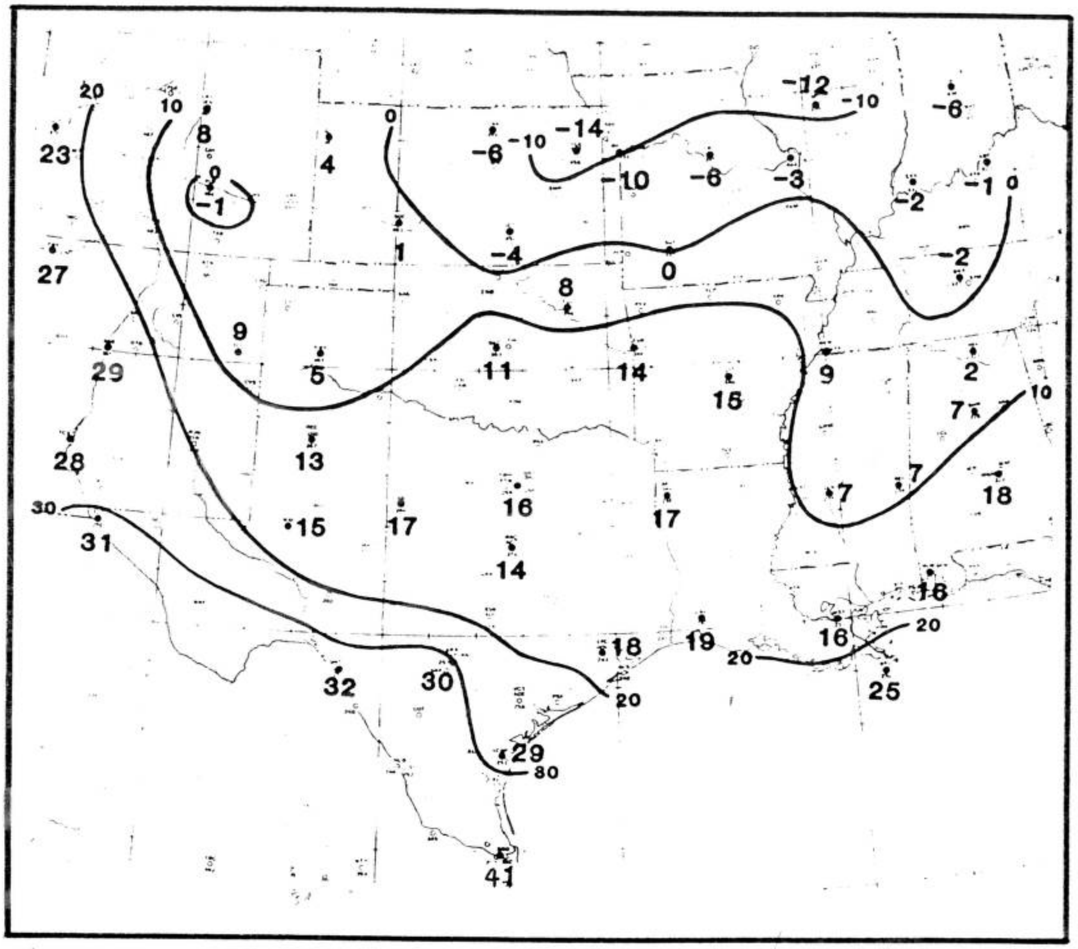

Figure 11. MOS forecasts of tomorrow's min produced from 0000 GMT data on December 24, 1983, and valid December 25, 1983.

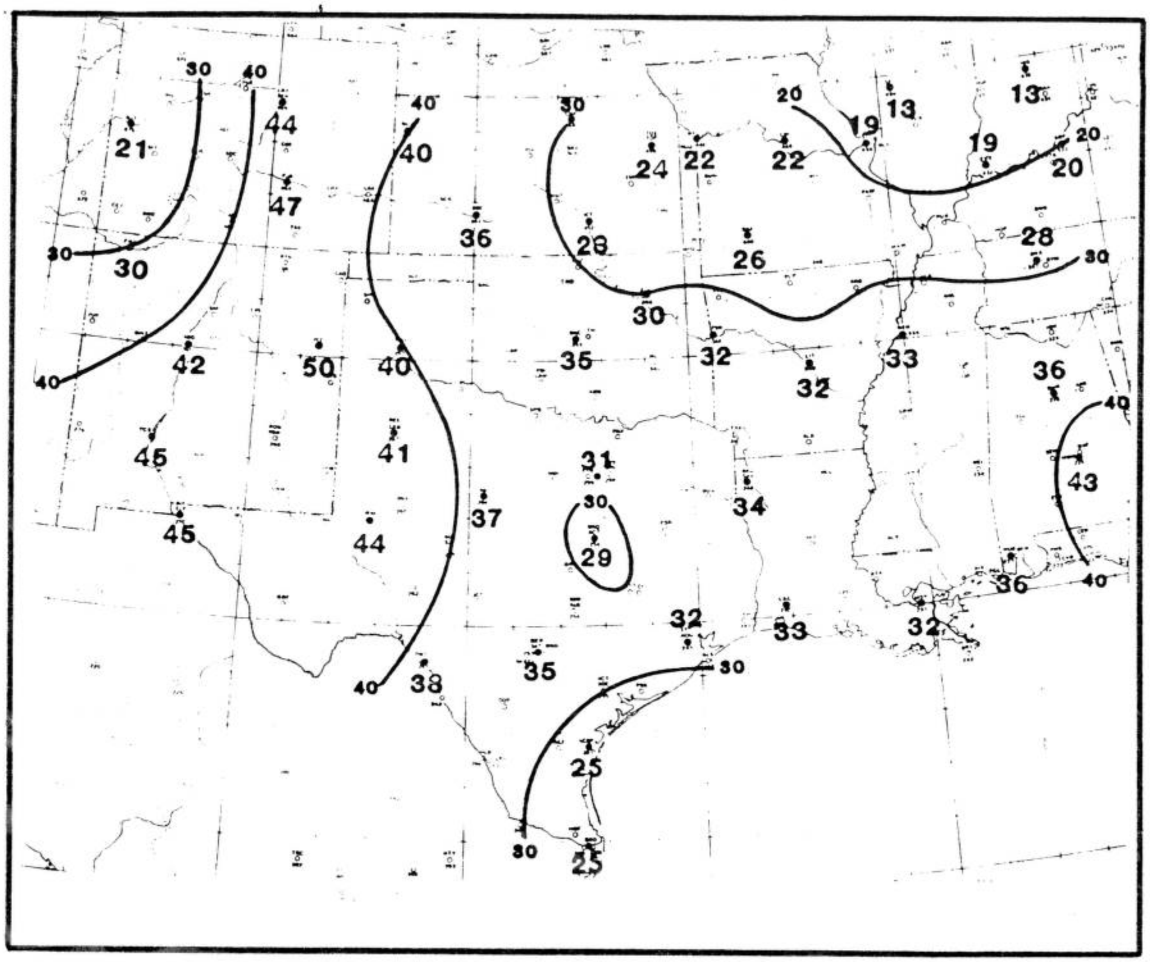

Figure 12. MOS forecasts of tomorrow's max produced from 0000 GMT data on January 20, 1984, and valid January 21, 1984.